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Nursing home care in The Netherlands: a nonparametric efficiency analysis

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Abstract

This paper analyzes the technical efficiency of Dutch nursing homes with respect to the use of labor inputs by means of Data Envelopment Analysis (DEA). In addition, the determinants of the efficiency scores are investigated using censored regression analysis. Special attention is paid to checking the robustness of the results to using different versions of DEA and to the econometric specification of the censored regression models.

Fifty percent of the nursing homes are fully efficient, according to the theoretically preferred frontier with constant or decreasing returns to scale. There is some evidence of a trade-off between labor input efficiency and the quality of care.

Keywords: Nursing home care; Data envelopment analysis; Censored regressions

JEL classification: I11, C49

1. Introduction

As in many Western countries, the costs of health care in The Netherlands have shown substantial increases in recent years, with a steady per capita annual real growth rate of about 0.6 percent [1]. It is widely conjectured that inefficiency of

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[1] Financieel Overzicht Zorg 1992 (Financial Review Care), Staatsuitgeverij, The Hague.

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health care institutions is an important contributor to the growth of health care costs.

In this paper I analyze technical efficiency with respect to the use of labor inputs of nursing homes in The Netherlands. The role of these institutions in the Dutch health care system has grown rapidly since the sixties. Although the expenditures on nursing homes have now stabilized at slightly more than ten percent of total health care costs, the importance of the nursing home sector is expected to show a further growth as the population ages.

The analysis in this paper uses efficiency scores based on Data Envelopment Analysis (DEA). In brief, DEA first identifies – nonparametrically – the production frontier, i.e. the set of homes that are producing a given number of outputs with the fewest number of inputs. The homes on the frontier are assigned the maximum score of one. Next, efficiency scores are calculated for the homes that are not on the frontier. Basically, the score of a nonfrontier home is the ratio of inputs used by an efficient home that produces comparable outputs to the inputs used by the nonfrontier home.

Having calculated the efficiency scores, I will investigate their determinants by means of censored regression models. The approach followed here is similar to the one in Nyman and Bricker (1989), who analyzed a sample of nursing homes in Wisconsin. In Nyman and Bricker's paper a constant returns to scale version of DEA was employed and the scores were analyzed using linear regression models. The present paper will pay special attention to the robustness of the results with respect to different versions of DEA scores and to the econometric specification of the censored regression models.

It should be kept in mind that Data Envelopment Analysis is essentially a relative efficiency criterion. The largest possible efficiency is in fact determined by the nursing home sector itself. As a consequence, DEA is not able to detect a possible inefficiency of the sector as a whole. On the other hand, it is extremely difficult to define an external standard of an efficient nursing home sector. This makes a comparison of the relative performance of nursing homes as in DEA perhaps even more useful a tool for efficiency analysis.

The present paper differs in focus from the econometric studies on nursing home care by McKay (1988), Gertler (1989) and Gertler and Waldman (1992). These papers have concentrated – all using U.S. data – on the costs of the nursing home industry employing cost function analysis and using cost data, with emphasis on the effects of different reimbursement schemes. [2] The present paper analyzes differences in technical efficiency using primal production data. Since technical efficiency is a prerequisite for cost efficiency, explicit attention for the

[2] While the effect of the reimbursement policy on efficiency is an important issue in the Netherlands, it is not amenable for analysis here, as all Dutch nursing homes face the same reimbursement scheme.

former is likely to provide important insight in the functioning of the nursing home sector.

The paper is organized as follows. Section 2 briefly outlines the principles of Data Envelopment Analysis. Section 3 discusses the data, which stem from a survey held in 1989 among all nursing homes in The Netherlands. It also briefly describes the (financial) incentives a Dutch nursing home faces. In Section 4 three different versions of DEA scores are calculated and compared. Section 5 presents the econometric analysis of DEA scores by means of censored regression models and reports some sensitivity checks. Conclusions are drawn in Section 6.

2. Nonparametric production frontiers

The concept of nonparametric production frontiers is best explained starting with the case where the production process requires one input (x) and generates one output (y) (Fig. 1). Each of the points A, B, C, and D represents a different home. In its most basic form, efficiency is defined as output per unit of input. Since the largest output/input ratio occurs at home B, B can be defined as the (only) efficient home. In this case the production frontier is represented by the ray through O and B.

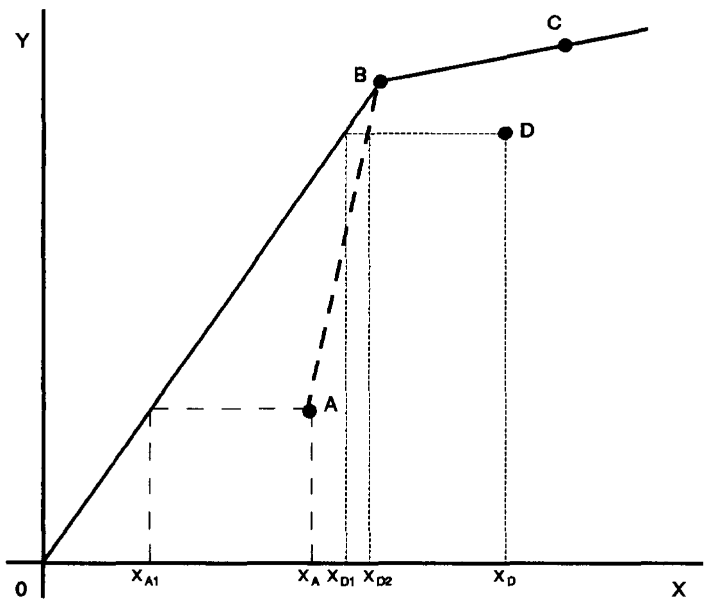

Fig. 1. Nonparametric production frontiers.

The efficiency of home A, for example, is now defined as x_{A1}/x_A (< 1). This definition of efficiency (which will be referred to as Data Envelopment Analysis – Constant Returns, *DEAC*), is in a sense strict as it assumes constant returns to scale. Suppose that the true production frontier exhibits decreasing (or constant) returns to scale and is represented by the convex set delimited by the line segments through O, B and C. Then being fully efficient according to *DEAC* requires not only using no more than the minimum input necessary to generate a given amount of output, it also requires choosing an optimal production size. Since the choice of the size of the production unit is often considered to be a separate issue, alternative efficiency measures have been proposed which allow the production frontier to exhibit constant or decreasing returns to scale (Data Envelopment Analysis – Constant or Decreasing Returns, *DEACD*) or variable returns to scale (Data Envelopment Analysis – Variable Returns, *DEAV*). The *DEACD* and *DEAV* measures are based on the production frontiers *OBC* and $X_A ABC$, respectively. For home D, the *DEAC* and *DEACD* efficiencies are both equal to x_{D1}/x_D; the *DEAV* efficiency of home D equals x_{D2}/x_D. For each home, the three scores satisfy $DEAC \leqslant DEACD \leqslant DEAV$. *DEACD* and *DEAV* may be viewed as measures of technical efficiency conditional on the size of the production unit. [3]

An important advantage of Data Envelopment Analysis – in addition to not having to prespecify a functional form for the production function – is that it is relatively easy to handle the case of multiple inputs and outputs. The efficiency scores are then defined as a weighted sum of outputs for a given weighted sum of inputs. The weights are chosen such that the efficiency score is as high as possible, subject to the restriction that all units have efficiency scores of at most one for that same set of weights. Let x_{in} be the quantity of the ith input of home n and y_{jn} the jth output; $i = 1,\dots,I$; $j = 1,\dots,J$ and $n = 0,1,\dots,N$. It has been shown that the efficiency score for the 0th home is obtained by solving the following linear programming problem:
maximize

$$DEA_0 = \sum_{j=1}^{J} u_j y_{j0} + w$$

[3] The DEA literature distinguishes between output and input efficiency. In the first case, a non-frontier home is characterized in terms of its failure to obtain maximal outputs from a given set of inputs. In the second case, it is characterized in terms of its failure to use minimal inputs to generate a given output. The two measures are equivalent in case of constant returns to scale. In the present paper, I focus on the second measure. The nursing home has the possibility to vary labor inputs, whereas the number of beds and patients is largely beyond its control.

subject to

$$\sum_{i=1}^{I} v_i x_{i0} = 1$$

$$\sum_{j=1}^{J} u_j y_{j0} - \sum_{i=1}^{I} v_i x_{in} + w \leqslant 0, \quad n = 0,1,\dots,N$$

$$u_j,\ v_i \geqslant 0$$

where maximization takes places with respect to the weights w, u_j and v_i, $j = 1,\dots,J$ and $i = 1,\dots,I$. Scale assumptions are imposed by restricting the range of w. If w is zero, the resulting frontier exhibits constant returns to scale (*DEAC*). With w limited to nonpositive values only, the linear programming problem yields a frontier with constant or decreasing returns to scale (*DEACD*). Finally, if w is unrestricted, a variable returns to scale frontier is obtained (*DEAV*). For further details, the reader may be referred to e.g. Banker et al. (1984) and Lewin and Knox Lovell (1990).

3. Data and indicators

The data set used in this paper is based on a survey held in 1989 among all 320 nursing homes in The Netherlands. The survey is conducted annually by the Dutch 'Nationaal Ziekenhuis Instituut' (National Hospital Institute) with the purpose to 'provide quantitative information on the nursing home sector'. Participation in the survey is mandatory. Due to missing observations with respect to some variables, 292 homes (91% of the population) are analyzed in this paper. As a consequence, sampling errors are likely to be very small. Since the survey forms have been filled out by the administrative staff of the nursing homes, who may assumed to be well-informed about their home, measurement errors are likely to be small as well.

Dutch nursing homes are financed on the basis of a prospectively determined fixed budget which primarily depends on the number of beds, the total number of days of treatment, and capital costs. If there is a surplus, it remains available to the home. New patients are assigned to homes by an independent so-called 'indication committee'. This committee of health care experts indicates what kind of health care institution is appropriate for patients in a particular district. In general, the possibilities for nursing homes to select patients are quite limited.

One of the problems of efficiency analysis of health care institutions is that the conceptual output – improved health status, or even more generally, improved quality of life – is difficult to measure. In DEA applications to hospital and nursing home performance, this has led researchers to use instead as measures of output the numbers of patients within different groups that have been treated. Ideally, the groups should be chosen such that all patients within a group experience similar benefits from the nursing home care in terms of their health status or quality of life. The present survey distinguishes between physically disabled patients and patients with psycho-geriatric disability, as well as between full-care and day care patients. Hence, four types of patients can be distinguished. A vector of four output types better reflects nursing home output than a single measure such as bed days or admissions, and allows for variation in input requirements for different types of patients. At the same time, it should be recognized that the four categories need not represent the best grouping of patients in terms of output. However, if an output group is not homogeneous, any variable related to within-group variation in output and labor input requirements (e.g. a measure of patient case mix) should turn out significant in the regression analysis of the efficiency scores.

Since the age distribution of patients in the four categories is known, one might also distinguish output categories on the basis of the age of the patients. A practical problem with this approach, however, is that it becomes unworkable when a large number of age categories are distinguished. Following Nyman and Bricker (1989) and Grosskopf and Valdmanis (1987), I therefore determine the efficiency scores using the four output categories and then use censored regression methods to determine whether variables that have not been used in defining the output categories have an effect on efficiency.

On the input side, six types of labor are distinguished: medical doctors, nurses, nurse trainees, therapists, general staff and other personnel (mainly temporary employees). As in Nyman and Bricker (1989), we do not include capital inputs. In Dutch nursing homes the management has control over labor inputs, but the use of capital inputs is largely beyond their ability to determine.

Table 1 shows that there are large differences in size between homes. The smallest home has only 8 beds, whereas the largest one has over 400. To get some insight in the variability in the input/output ratios, I have calculated for each home and for each labor category the ratio of labor input to output, using the sum of the four types of output as a rough total output measure. Table 2 reports the mean, standard deviation and minimum and maximum values of the ratios. Since the informational content of latter two may be limited due to outliers, I have also reported the first and ninth decile of each ratio. Table 2 shows that, again, the differences are formidable. For example, some homes have four times as many medical doctors per patient than other homes. While these ratios are of course only a crude measure of input/output variability, the numbers justify further investigation. The raw data also show that six homes are strictly dominated by one or more other homes. [4]

[4] A home is said to be strictly dominated if there exists a least one other home which produces at least the same amount of all outputs while using less of all inputs.

Table 1
Descriptive statistics [a]

	mean	st.d.	min	max
Outputs				
Full-care patients				
physical disability	80.0	61.3	0	268
psycho-geriatric disability	74.7	70.0	0	361
Day care patients				
physical disability	3.2	4.3	0	21
psycho-geriatric disability	2.8	4.4	0	27
Nursing home has day care patients	0.658			
Labor inputs [b]				
medical doctors	2.3	2.05	0	18.1
nurses	81.0	40.01	1.1	239.9
nurse trainees	34.2	23.7	0	149.6
therapists	13.8	8.0	0	44
general staff (...)	41.9	22.2	0.5	148.5
other (...)	9.3	10.0	0	56.7
Explanatory variables				
No. of beds	157.4	74.22	8	418
Occupancy rate	0.978	0.060	0.282	1.047
Proportion patients over 85	0.361	0.106	0.0	0.750
Length of stay index [c]	0.655	0.124	0.0	1.000
Hospital affiliation	0.079			
Volunteers	0.949			
No physical therapy	0.024			
Nurse trainees	0.856			
Patients council	0.541			
Council of patients' relatives	0.644			
Procedure for complaints	0.678			
Unrestricted visiting hours	0.921			
Region				
Big city	0.154			
North	0.127			
East	0.192			
South	0.233			
Religious affiliation				
Catholic	0.209			
Protestant	0.229			

Table 1 (continued)

	mean	st.d.	min	max
Type of management				
Medical doctor in management	0.305			
General manager in management	0.729			
Medicine supply system				
Own dispenser	0.185			
Independent external dispenser	0.545			
'Central' dispenser	0.082			
Hospital dispenser	0.380			
No. of obs.: 292				

[a] If only the mean is reported, the variable is a 1/0 dummy; daily averages in 1989.
[b] In full-time equivalents
[c] Proportion of patients in the home present uninterruptedly during the whole year.

Table 2
Simple input/output ratios

	mean	st.d.	min	max	1st decile	9th decile
medical doctors	0.013	0.011	0	0.119	0.005	0.019
nurses	0.511	0.116	0.183	1.659	0.403	0.613
nurse trainees	0.201	0.103	0	0.8011	0.075	0.306
therapists	0.081	0.030	0	0.307	0.047	0.109
general staff	0.260	0.086	0.022	1.17	0.174	0.330
other (...)	0.058	0.054	0	0.340	0.000	0.128

4. The efficiency scores

The outcome of calculating the *DEAC* and *DEACD* scores is summarized in Table 3. The *DEAV* score turned out to be equal to the *DEACD* score for all

Table 3
DEA efficiency scores

	mean	st.d.	min	max
DEAC score	0.802	0.152	0.221	1.000
Home is on DEAC frontier	0.205			
DEACD score	0.936	0.096	0.293	1.000
Home is on DEACD frontier	0.500			

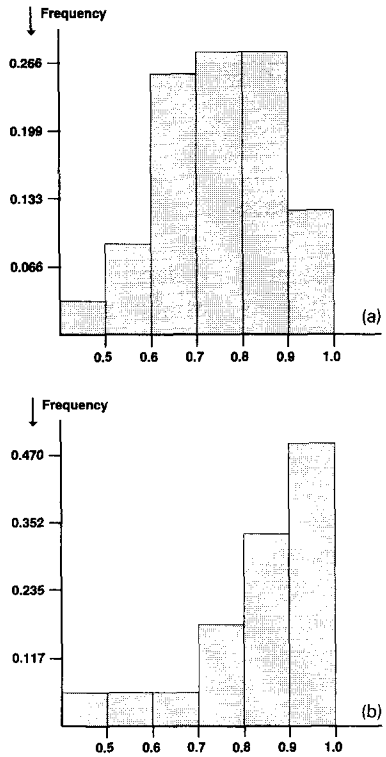

Fig. 2. a. Distribution of DEAC scores (nonfrontier homes). b. Distribution of DEACD scores (nonfrontier homes).

homes but two, with the differences for these two homes being small. Therefore, *DEAV* will not be considered in the sequel. The result implies that the nursing home sector operates under constant or decreasing returns to scale, at least with respect to labor inputs. For *DEACD* the percentage of homes operating on the frontier is 50. The average efficiency score for nonfrontier homes is 0.87, implying that non-efficient homes use on average roughly 13 percent more inputs per unit of output than efficient homes. According to the stricter efficiency criterion of *DEAC*, 21 percent of the homes operate efficiently, with an average efficiency score of 0.75 for nonfrontier homes. The *rank correlation* between *DEAC* and *DEACD* is computed at 0.824. So, although the difference between *DEACD* and *DEAC* is substantial in terms of the numerical values of the scores, the efficiency ranking of the homes is reasonably stable with respect to the two versions of DEA. The distribution of scores of nonfrontier homes is visualized in Fig. 2 for both *DEAC* and *DEACD*.

For the present analysis, the *DEACD* criterion is more appropriate than the *DEAC* criterion, since the former eliminates the effects of the size of the home on efficiency. In the short run, decisions with respect to size are largely beyond control of the management. Moreover, size decisions are severely constrained by government regulation. In the sequel we will therefore concentrate on the *DEACD* criterion.

5. An econometric analysis of the efficiency scores

The second purpose of this paper is to relate the scores to a number of observed characteristics of the homes. If efficiently operating homes appear to have certain common characteristics, this may allow us to identify possible causes of inefficiency. Since by definition there is always a nonnegligible proportion of observations reaching the maximum score of one, censored regression models will be employed. In Nyman and Bricker (1989), a linear regression model was used to explain the score differences. It is well-documented, however, that OLS applied to a censored regression model yields estimates that are asymptotically biased toward zero; see Greene (1981). [5]

Three explanatory variables will be included that serve as indicators of the size of the nursing home, the *number of beds*, the *number of beds squared* and the presence of *day care* facilities. Since *DEAC* assumes that the efficient frontier exhibits constant returns to scale, the size variables are probably important explanatory variables in the *DEAC* equation. In the *DEACD* equation, however, they should be not significant, because *DEACD* measures efficiency conditional on a given size, as noted before. A higher *occupancy rate* will tend to result in a higher efficiency score, since the management will generally not be able to smoothly and quickly adapt the size of the staff to fluctuations in the number of patients.

An important aspect of efficiency analysis in health care is the quality of care patients receive. To the extent that higher quality requires more inputs, a high efficiency score may simply reflect poor quality of care. To determine the relationship between these two dimensions of nursing home performance, one needs information on quality. Although direct information on quality is absent in the present data set, four variables will be included that are related to the quality of care, the presence of a *patients' council*, the presence a *council of patients' relatives*, the presence of a *procedure for handling complaints* and a variable indicating the absence of restrictions on *visiting hours*. The nursing homes have no (legal) obligations with respect to these arrangements. Their presence may reflect a nursing home's commitment to take into account the opinions of patients and their relatives and to optimize the quality of care. The presence of *nurse*

[5] If the regressors follow a normal distribution, all estimates are asymptotically biased by the same proportion: the proportion of nonlimit observations.

trainees might have a negative effect on the efficiency score, since their training requires time and attention from other personnel categories. The absence of *physical therapy* lowers labor input requirements, but it also lowers the quality of care. (Only 7 out of the 292 homes have no physical therapy.) Using *volunteer labor* should have a positive effect on the efficiency score, as far as it acts as a substitute for regular labor. I also include a variable indicating whether the nursing home is *affiliated to a hospital*. In most cases an affiliation means that the nursing home uses facilities and services from the hospital, for example meal preparation. It is therefore expected to have a positive effect on the efficiency score. The effect of the presence of a *medical doctor in the management* team is difficult to sign on theoretical grounds. On the one hand there may be a negative effect because there is more emphasis on medical treatment, which may in turns result in a larger medical and semi medical staff. On the other hand, medical doctors may be more familiar with a nursing home environment than general managers, and therefore operate more efficiently. The care requirements of patients are obviously important for the resource requirements of a home. The present data set does not contain information on resource utilization groups, but I will include two variables which, to some extent, control for the effect of patient case mix. The first is the *proportion of patients over 85*. Older patients are likely to require more resources than younger patients. The second variable is the proportion of patients present in the home uninterruptedly during the whole year, which is an index of the average *length of stay* in the home. Patients with longer stays may require more resources because they represent chronic cases. The expected effect of both variables on efficiency is therefore negative. The *medicine supply system*, the *region* and the *religious affiliation* of the home are control variables, the effect of which is not clear a priori. (Since homes may use more than one medicine supply system, variables for all four systems are included.) Some descriptive statistics on the variables are listed in Table 1.

The first column of Table 4 presents the results of a Probit model describing whether a home is on the *DEACD* frontier or not. In the second column Tobit estimates with the *DEACD* score as the dependent variable are reported. To facilitate comparison of the Probit and Tobit results, the Probit estimates have been normalized using the Tobit estimate for σ (0.147). Notice that the estimates in both equations have the same signs almost without exception, with the differences in asymptotic t-values being small.

As expected, the significance of the size variables is virtually absent in the *DEACD* model. In the *DEAC* equations (not reported) the size variables are indeed the most dominant explanatory variables. [6] The *DEAC* estimates indicate

[6] The Tobit DEAC coefficient estimates for the size variables are $-0.121\text{E}-02$ (t-value -2.0) for the number of beds, $0.170\text{E}-05$ (t-value 1.2) for the number of beds squared and 0.210 (t-value 8.5) for the presence of day care.

Table 4
Estimation results Probit and Tobit models (t-values in parentheses)

Dependent variable	DEACD score (Probit)	DEACD score (Tobit)
Explanatory variables		
Constant	−0.453	0.384
	(−0.9)	(1.0)
No. of beds	−0.297E−03	0.123E−03
	(−0.4)	(0.2)
No. of beds squared	0.209E−05	0.147E−05
	(1.1)	(0.9)
Day care	0.052	0.044
	(1.6)	(1.7)
Occupancy rate	0.610	0.651
	(1.1)	(1.6)
Prop. patients 85 +	−0.037	0.479
	(−0.3)	(0.4)
Length of stay index	−0.167	−0.127
	(−1.5)	(−1.3)
Hospital affiliation	0.029	0.065
	(0.6)	(1.6)
Volunteers	0.075	0.083
	(1.1)	(1.4)
No physical therapy	1.034	1.081
	(0.0)	(0.1)
Nurses' training	−0.148	−0.102
	(−3.1)	(−2.4)
Patients council	−0.061	−0.040
	(−2.4)	(−1.8)
Council of patients'	−0.023	−0.036
relatives	(−0.8)	(−1.5)
Procedure for	−0.001	−0.022
complaints	(−0.0)	(−0.9)
Unrestricted visiting hours	−0.012	−0.020
	(−0.3)	(−0.5)
Big city	0.124	0.070
	(3.0)	(1.9)
North	0.019	−0.015
	(0.2)	(−0.4)
East	−0.016	−0.006
	(−0.4)	(−0.2)
South	0.011	−0.009
	(0.3)	(−0.3)
Catholic	−0.007	0.008
	(−0.2)	(0.3)
Protestant	−0.055	−0.018
	(−1.8)	(−0.7)
Medical doctor	0.001	−0.002
in management	(0.0)	(−0.1)

Table 4 (continued)

Dependent variable	DEACD score (Probit)	DEACD score (Tobit)
General manager in management	−0.043 (−1.4)	−0.029 (−1.2)
Own dispenser	0.007 (0.2)	0.011 (0.4)
Independent external dispenser	0.067 (1.5)	0.055 (1.4)
'Central' dispenser	0.042 (0.7)	0.062 (1.3)
Hospital dispenser	0.050 (1.1)	0.026 (0.6)
σ		0.147 (15.5)
Pseudo R^2		0.137
log likelihood	−173.55	−15.58

that homes with an optimal size with respect to labor input efficiency have day care facilities, combined with a small number of beds. The absence of significant size effects in the *DEACD* equations shows that this criterion effectively eliminates the effects of size on efficiency, as it should.

As judged from the negative signs of the coefficients on all four quality indicators, these variables have a net effect of absorbing labor resources. A likelihood ratio test on the absence of their joint effect yields a $\chi^2(4)$ test statistic of is 8.16 ($p = 0.086$) for the Tobit model and of 6.78 ($p = 0.148$) for the Probit model. These results provide some evidence on the existence of a negative relationship between the quality of care and the efficiency in a home, although statistically speaking the evidence is not strong.

The presence of nurse trainees in the home has a negative effect on the efficiency score, as expected. However, it should be kept in mind that homes with nurse trainees produce an additional output in terms of a contribution to the certification of nurses (which is not included explicitly in the DEA calculations). The occupancy rate, being affiliated to a hospital and using volunteer labor have the expected positive effects on efficiency. The other explanatory variables are generally insignificant. Note that the insignificance of the proportion of patients over 85 and the average length of stay does not necessarily indicate that patient case mix has no effect on the efficiency score. It may also simply mean that these two variables are poor proxies for patient case mix.

The pseudo R^2 value of the Tobit equation indicates that the larger part of the variation of scores remains unexplained. Obviously, various potential determinants have not been included in the analysis, such as the quality of the buildings and the domestic environment, more precise information on the care requirements of patients and the quality of the management of the home.

Since the statistical properties of the maximum likelihood estimator of censored regression models strongly hinges on specific distributional assumptions (identically normally distributed independent error terms), the validity of the models has been checked in several ways. First, a truncated regression model (which uses the nonfrontier observations only) was estimated. The Tobit model emerges in the special case where the parameter sets in the Probit model and the truncated regression model are equal. If the parameter sets are equal the loglikelihood of the Tobit model is simply the sum of the Probit and truncated regression loglikelihoods. The test statistic, which follows a $\chi^2(27)$ distribution, is computed at 44.2, which is just in between the critical values at the 5% and 1% level. The result may be interpreted as providing no evidence of a clear rejection of the Tobit model. Secondly, as a general check on the specification of the model, the standard errors were computed in two different manners. [7] The differences between both sets of standard errors appeared to be very small, indicating that there is no evidence of misspecification. Thirdly, to check the sensitivity with respect to functional form, the Tobit equation was re-estimated using the rank indices of the scores as the dependent variable. [8] The estimates remained virtually unchanged, in terms of sign and relative size as well as in terms of significance. This implies that the results are robust against monotonically increasing transformations of the dependent variable.

6. Conclusions

In this paper the technical efficiency of Dutch nursing homes with respect to the use of labor inputs has been analyzed by means of Data Envelopment Analysis. Fifty percent of all nursing homes operate efficiently, according to the theoretically preferred frontier with constant or decreasing returns to scale. The

[7] The t-values reported in Table 4 are based on the outer product of the gradient of the loglikelihood contribution per observation. A second set of t-values was based on the negative inverse of the Hessian of the loglikelihood. If there is no misspecification these two sets of standard errors are asymptotically equal (cf. White, 1982).

[8] The rank index is constructed as follows. First, the n homes are ordered according to the value of the efficiency score. Next, the home with the lowest score is assigned a value of one, the home with the one but lowest score is assigned a value of two, et cetera. The m homes with the maximum score of one are assigned a value of $(n - m + 1)$. Finally, the numbers are scaled onto the $0-1$ interval by dividing all numbers by $(n - m + 1)$.

non-efficient homes use on average roughly 13 percent more labor inputs per unit of output than efficient homes.

A number of variables which are likely to act as quality indicators appeared to have a negative effect on efficiency. The result indicates that a higher quality requires more labor resources, but the statistical evidence is not strong. A more conclusive picture of the relationship between quality and efficiency requires the collection of data on an extensive set of quality indicators, as well as more detailed information on the care requirements of patients. The set of quality indicators might include rankings of outside experts.

From a policy point of view, the positive effect on efficiency of hospital affiliation and the use of volunteer labor are among the most interesting results. Although several coefficients turned out significant, the scores could be explained by differences in observed characteristics of the homes to a limited extent only. Of course, this does by no means detract from the usefulness of the data envelopment approach as a device to signal efficiency differences.

While the data envelopment technique has shown to be a potentially important tool in efficiency analysis, the practical usefulness of empirical applications is, of course, largely determined by the quality of the available data. In the present paper, the data used are less than ideal. A prerequisite for improved future empirical analysis of nursing home performance is the joint availability of comprehensive information on patient case mix, quality of care and output. In particular, output dimensions can be measured more directly. As in Linn et al. (1977) one may collect information on a patient's survival and changes in functioning (improved, unchanged, or deteriorated) and location (discharged, still in home, in hospital) after admission.

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